ON THE DEVELOPMENT OF MULTI-MATERIAL AUTOMATED FIBRE PLACEMENT TECHNOLOGY

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SUMMARY

While Automated Fibre Placement machines are commercially available and being utilised in some industrial settings for the automated manufacture of preforms, full definition of the material-dependent process parameters and their effect on the preform quality/features are not yet thoroughly understood. Through characterisation of novel, commercial tapes (thermoplastic prepreg and dry-fibres bindered tapes) and analysis of basic deposition trials, the authors define and compare the processing variables required to lay-up the different materials.

Keywords: Automated Fibre Placement, AFP, Preform, Thermoset, Thermoplastic, Dry-Fibre, Robotic manufacturing

MULTIMATERIAL AUTOMATED FIBRE PLACEMENT

Technology overview

Automated Fibre Placement (AFP) equipment capable of depositing narrow thermosetting prepreg tapes has been available on the market since the early 90s and it is currently used in the manufacture of some structural composite components [1]. The technology is now extending its capability into the field of thermoplastic and dry, bindered raw materials, although the use of such materials in the context of AFP at industrial level is currently scarce.

Several cost models have attempted an analysis of the potential benefits and costs associated with the implementation of AFP within established or new production environment and initial results have been sometime contradictory; however, the automated process has the undeniable advantage of minimising manual materials handling, therefore reducing operator dependency, and increasing production rates while facilitating quality control. Extension of the technology to thermoplastic matrix composites and out-of-autoclave processes has raised the interest of several potential users, hence the need for a systematic and critical analysis of the process variables.

Process physics

While the machine setup is arguably the same regardless of the nature of the raw material used (namely an automated deposition tool laying down a set of narrow tapes locally heated by a heating source), the physics of the processes can be very different. The heat and pressure applied to prepregs have the objective of increasing locally the material tackiness and reducing the bulk factor [2], while in the case of thermoplastics the process is closer to proper melt-welding, with pressure control used to limit void rebound [3]. When dry tapes are used, the binder (typically epoxy based) is locally activated by the combined action of heat and pressure and, if the parameters are correct, holds the tapes in the desired place and orientation [4].

Materials characterisation

Commercially available tapes were characterised through a combination of optical microscopy, scanning electron microscopy and thermal analysis. The differences between the different material types were highlighted, and the impacts on the choice of process parameters discussed. The enhanced understanding of the different materials obtained through characterisation is used to determine the process parameters which are critical for the automated deposition of each material type.

Process characterisation

The temperature distribution in the process was determined experimentally, focusing on the temperature distribution along the width of the roller, the temperature change when the material passes the heating and compaction zone and the temperature distribution through the thickness of the layup.

Conclusions

The material and the processes are highly interlinked, and the material drives the requirements for the processing parameters. A large number of variables affect the temperature distribution. The current material characterisation methods do not replicate the process due to the exceptionally high heating rate in the process, but can provide a valuable first approximation.

Further work will concern the effects of the AFP process parameters on the subsequent process steps: consolidation for thermoplastic material and impregnation for bindered dry fibres.

References

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